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INHALABLE PARTICULATE NETWORK

STANDARD OPERATING PROCEDURES

AND

TECHNICAL MANUAL

ARB-139-87

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PREFACE

Based on the conclusions of a preliminary study an experimental provincial inhalable particulate sampling network was established in late 1983. The network is to provide the Province with a system whereby health - relative measurements and source apportionment data could be obtained simultaneously. Automatic dichotomous samplers which are operated by regional technicians are located at various sites. Particulate sampled on teflon membrane filters would be weighed and elementally analyzed (by energy dispersive x-ray analysis) at Laboratory Services Branch.

It was felt that if the network could determine the amount of particulate a resident may inhale, and also the principal sources of the particulate, then the monitoring system would be truly effective.

The four major objectives of the program are:

1) To provide the capability to determine inhalable particulate levels at a number of sites in Ontario;

2) To co-ordinate all aspects of network operation. This includes sampler upkeep, filter weighing and analysis, and sample transport;

3) To provide data to evaluate source apportionment models suitable for airshed assessment; and

4) To provide data and expertise for the setting of an inhalable particulate standard.

This manual details standard operating procedures of the sampling network and is to be used in conjunction with the Quality Assurance Plan. The manual is based on:

1) guides, papers, reviews and internal correspondence from network operations;

2) Sierra-Andersen 244 and 245 instruction manuals; and

3) E.P.A. Operating Procedure for Sierra 244.

Much of the material has been updated and rewritten to conform to current practices.

PRÉFACE

À partir des conclusions d'une étude préliminaire, on a créé fin 1983 un réseau provincial expérimental d'échantillonnage des particules respirables. Ce réseau est censé apporter à la province un système fournissant simultanément des mesures en matière de santé ainsi que des données sur la contribution des sources d'émission. On a installé en divers sites des échantillonneurs automatiques dichotomiques, servis par des techniciens régionaux. Les particules récoltées dans des filtres à membrane en Teflon doivent être pesées et leurs constituants analysés (par radiographie à dispersion d'énergie) à la Direction des services de laboratoire.

Si le réseau permet de déterminer la dose de particules respirée par les habitants, ainsi que les sources principales d'émission, le système de surveillance est vraiment efficace.

Voici les quatre grands objectifs du programme :

1) Permettre de déterminer les concentrations de particules respirables à une série d'endroits en Ontario

2) Coordonner tous les aspects du fonctionnement du réseau, entre autres : entretien des échantillonneurs, pesage et analyse du contenu des filtres et transport des échantillons

3) Recueillir des données permettant d'évaluer la contribution des diverses sources d'émission atmosphérique

4) Recueillir des données pour fixer des normes en matière de concentration des particules respirables.

Ce manuel expose dans le détail les méthodes standard à employer dans le réseau d'échantillonnage et doit être employé de concert avec le plan de contrôle de la qualité. Ce manuel est basé sur :

1) des guides, rapports, enquêtes et correspondance interne en rapport avec le réseau d'échantillonnage

2) les manuels d'instructions pour Sierra-Andersen 244 et 245

3) les méthodes du bureau de la protection de l'environnement américain (E.P.A.) pour Sierra 244.

Le plus gros du texte a été revu et mis à jour en fonction des méthodes actuelles.

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1.0 Description of the Sierra-Andersen Model 244 and Model 245 Dichotomous Samplers.

1.1 General Description

The dichotomous sampler was modelled after inertial virtual impactors which fractionate particles according to their aerodynamic characteristics. Developed from the cascade centripeter, it was designed to sample those particles up to 10 um in aerodynamic diameter and to separate them into the coarse (2.5 to 10 um) or the fine fraction (less than 2.5 um). The size-segregated aerosol is filtered by a chemically inert teflon membrane filter. The aerosol on the filter can be analyzed later in the laboratory. The dichotomous sampler has a much lower sampling rate than the Hi-Vol, sampling 24 m^3 in each 24-hour period.

The inlet head is designed to allow particles less than 10 um to enter the sampler. Particles greater than this are too prone to gravitational settling to enter the inlet tube. The head is cylindrically symmetric to provide uniform sensitivity to particles, independent of the wind direction. Ideally, the inlet only allows particles which are capable of entering the respiratory system into the sampler.

From the inlet head, the sampled particles pass down through a vertical tube to the virtual impactor, which separates the particles into their respective coarse and fine modes. In this regard, it simulates a conventional impactor, however, instead of an impactor plate, it creates a void relative to the inertial flow. Larger particles are carried into this void because of their greater inertial momentum. Once the particles are aerodynamically fractionated into two air streams, they are collected on teflon filters.

The dichotomous sampler uses two 37 mm teflon membrane filters (2 um pore size) for each sample. One filter collects fine particles (less than 2.5 um in diameter) and the other collects coarse particles (2.5-10 um in diameter). Teflon is considered to be chemically inert and no pollutant-filter artifact has yet been discovered with this sampling system.

The teflon membrane filters used with the dichotomous sampler are manufactured with a light polyolefin ring attached to the perimeter. This ring keeps the filter from folding, wrinkling, and rolling during use.

The clean preweighed filters are placed in polypropylene ring-type filter holders which are labelled with the site and filter numbers. Fine filters are placed in a white ring and coarse filters in a yellow ring. The ringed filters are packaged in clean labelled petri dishes for transport. A set of 20 filters (approximately one months supply per site) are placed in a wooden carrying case for pick-up by the region.

After sampling, the filters are returned to the lab and reweighed. The difference between the loaded and the original filter weights represents the total particles sampled. The air volume of the sample (usually 24 m^3) is used to determine the airborne particle concentration. Correction factors are applied because some fine particles are deposited on the coarse filter. After weighing, loaded filters are retained for energy-dispersive x-ray analysis.

1.2 Models 244 and 245 - General Description

Two models of dichotomous samplers are currently used in the Inhalable Particulate (IP) Network. The Sierra Model 244 Manual Dichotomous Sampler (Figure 1.1) consists of two modules: the sampling module and the flow control module. This sampler is equipped with a digital timer/programmer and elapsed time indicator. The digital clock has an LED display and d.c. battery standby.

The Sierra-Andersen Model 245 Automatic Dichotomous Sampler also consists of two modules. The sampling module utilizes the same inlet and virtual impactor mechanisms as the Model 244, however, the sample holders are expanded to accommodate more filters. The module incorporates a circular filter tray which accommodates 20 samples (40 filters). The tray is mounted on a revolving carousel and enclosed in a weather resistant shelter. The tray can be programmed to load samples at preset times and dates. The programmer is located in the timer module. This timer/programmer is essentially a Model 244 module with expanded capabilities. A control cable connects the timer/programmer module to the sampling carousel.

See Table 1.1 for Sierra-Andersen Dichotomous Sampler general specifications.

1.3 Flow System Description

Figure 1.1 illustrates the principle of operation of the Sierra dichotomous sampler; Fig. 1.1 also provides a flow schematic. The coarse-particle flow Q_C (0.1 m^3/hr) is controlled by its flow selector valve, which feeds into pressure gauge P_2 at the inlet of the pump. Flow Q_C is relatively constant except for small decreases in P_4, which can occur during sampling. Because Q_C is small, an error in Q_C can cause an error of not more than 10 percent in total particle mass concentration.

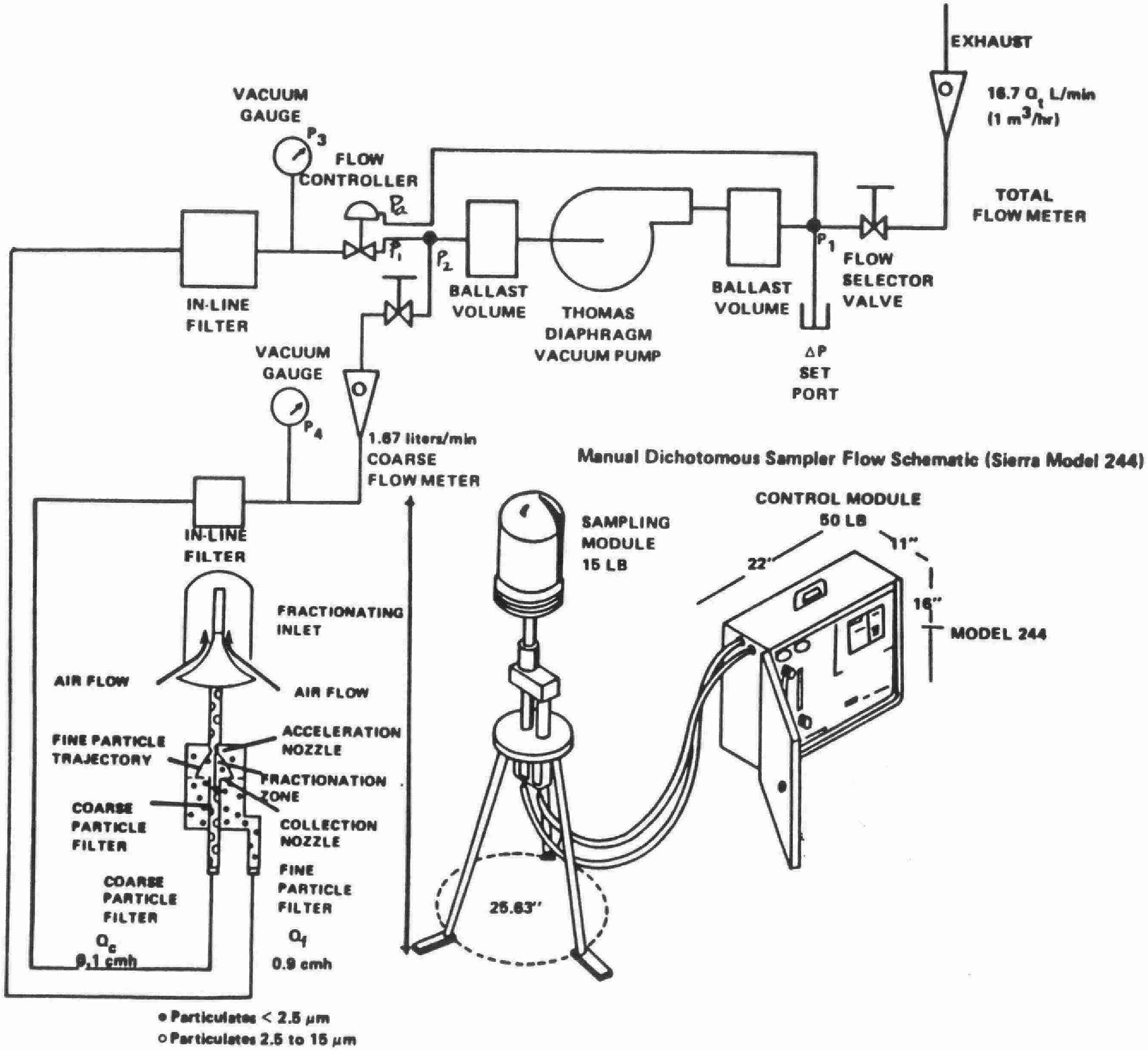


Figure 1.1 Manual dichotomous sampler used in IP Network–Sierra Model 244.

TABLE 1.1 SPECIFICATIONS FOR SIERRA-ANDERSEN DICHOTOMOUS SAMPLERS

Collection efficiency	Mass median diameter at 50 percent collection efficiency for equivalent spherical particles of 1 g/cm^3 is 2.5 um; sigma "g" = 1.2.
Internal losses	Maximum value over range of 0 to 20 um is less than 1 to 2 percent and occurs at 2.5 um. Average loss for all particles is less than 1 percent.
Flow rates	Total flow: 1 m^3/hr, or 16.7 L/min., fine-particle flow: 0.9 m^3/hr or 15.0 L/min; coarse-particle flow: 0.1 m^3/hr, or 1.67 L/min.
Flowmeters	Precision rotameters, $\pm$1.5 unit accuracy at above flow rates.
Concentration ratio	9:1 Fine flow:course flow.
Vacuum pump	Diaphragm type, split phase motor, ¼ hp.
Timer/programmer	Sierra-Andersen digital timer/programmer; built-in; all functions digital and quartz crystal controlled, has digital clock with ½-in. LED display and d.c. battery standby; includes first sample period delay up to 9 days, sampling period of 1, 2, 3, 4, 6, 8, 10, 16, 20, or 24 hours, and skipped time between sampling periods of 1 to 9 days.
Elapsed time indicator	XXXX.XX hours; nonresettable.
Filter media	37-mm diameter Teflon membrane.
Filter holder	Circular, polypropylene, 44 mm O.D.
Interconnecting tubing	10m long; 3/8 in. O.D. for fine-particle flow; ¼ in. O.D. for coarse-particle flow.
Aerosol inlet	10-um nominal cutpoint over approximately 0 to 20km/hr wind speed range; includes bug screen.
Power required	115 V a.c. ±15 percent, 50-60 Hz, 200 W.

1.3.1 Control Panel

The control panel is positioned behind a weathertight door and contains vacuum gauge, rotameter, and digital timer/programmer displays. The control panels for Models 244 and 245 are shown in Figures 1.2 and 1.3, respectively.

The functions of the various displays and controls are described below.

1.3.2 Flow Control and Measurement

Flow selector valves and rotameters are provided for setting the total and coarse-particle flow rates (Q_t and Q_c in Figure 1.1). Vacuum gauges measure the pressure drop across the fine and coarse particle filters (P_3 and P_4 in Figure 1.1).

1.3.3 Digital Timer/Programmer

1. Clock:
   a. Display: LED; 0.5 in. high; hours and minutes; 24-hr format.
   b. Time Base: Quartz Crystal.
   c. DISPLAY Switch:
      - PRESENT TIME is displayed.
      - SAMPLE START TIME--Time of day when sampling period starts is displayed.
      - FAST/SLOW switch (both momentary; used for setting TIME OF DAY and SAMPLE START TIME)--
        FAST--Minutes advance at 60 Hz rate.
        SLOW--Minutes advance at 2 Hz rate.

2. SAMPLE AFTER Switch:
   Sample After X Days. Delays start of first sampling period 0 to 9 days in 1-day increments.

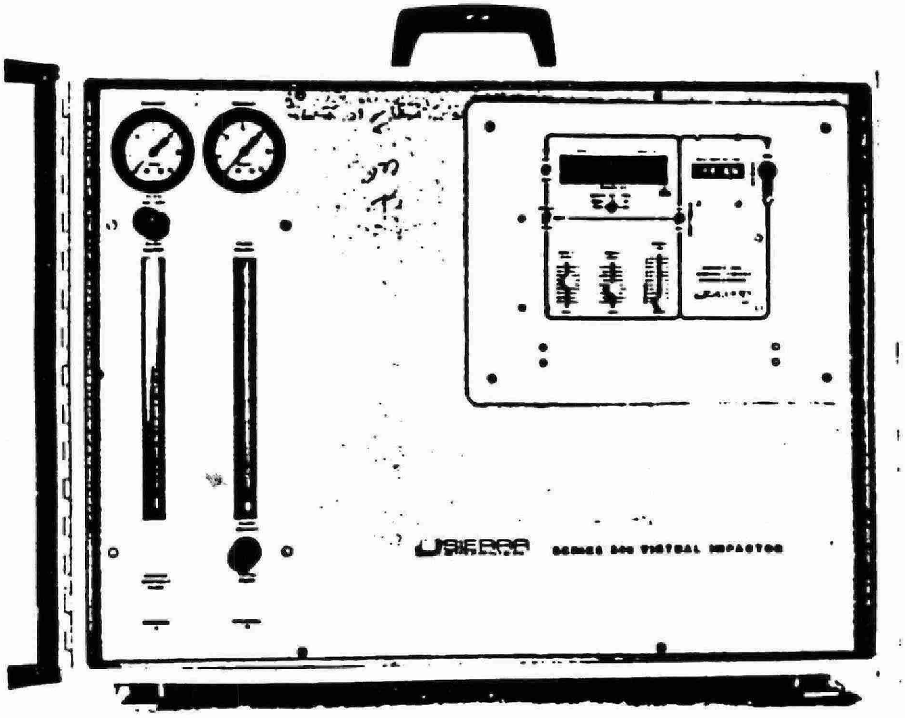


Figure 1.2 Control Module for Sierra Model 244 Dichotomous Sampler

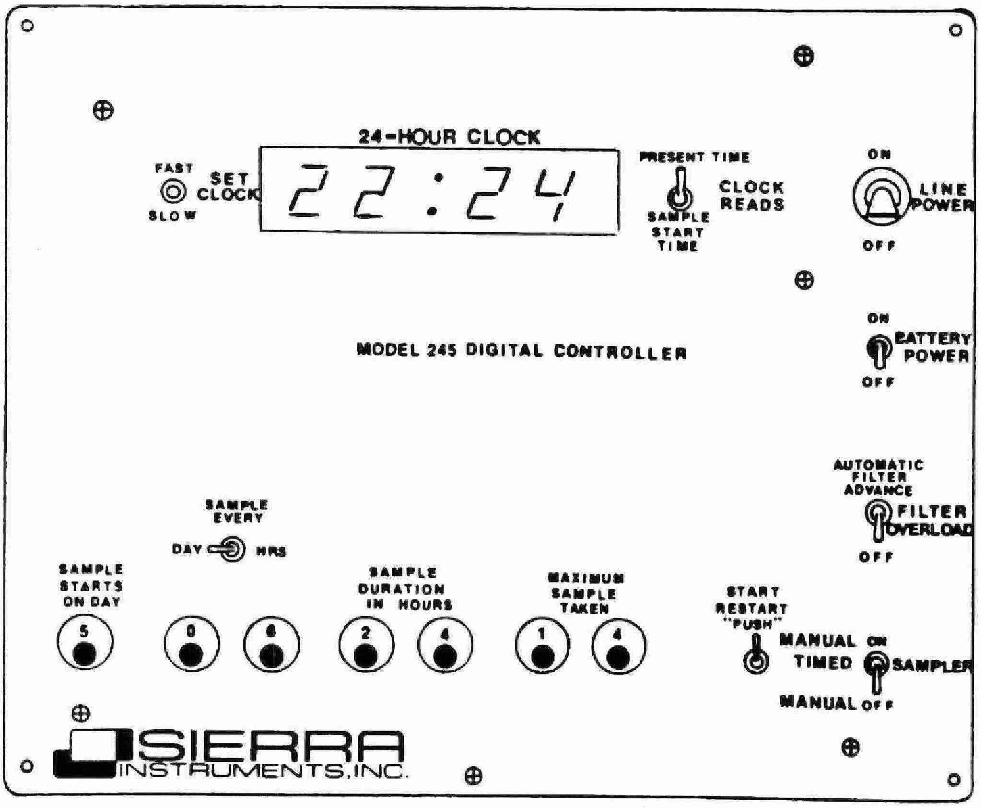


Figure 1.3 Control Panel for Model 245 (Automatic) Dichotomous Sampler

3. SAMPLE EVERY Switch:
   Sample Every Y Days. Permits sampling every 1 to 9 days in 1-day increments.

4. SAMPLE FOR Switch:
   Sample for Z hours. Sets number of hours sampler stays on--1, 2, 3, 4, 6, 8, 10, 16, 20, or 24 hours.

5. SAMPLER Switch:
   a. ON-Sampler is turned on manually; timing is unaffected and elapsed time runs.
   b. TIMED--Sampler is controlled by timer.
   c. OFF--Sampler is turned off; timer is unaffected.

6. SET Switch: Normally in DISPLAY position.
   TIMER--Turns sampler off; resets all time functions (SAMPLE AFTER, SAMPLE EVERY, and SAMPLE FOR), except the present time and SAMPLE START TIME.

7. Power Fail: Flashing time display digits with DISPLAY switch on indicates battery power failure. All timed functions must be reset.

8. TOTAL SAMPLING TIME Display: Indicates the total elapsed time the sampler is on; nonresettable; 9999.99 hours (416 days) before roll over.

9. POWER/CIRCUIT BREAKER switch (115/230 V a.c., 15 A):
   a. UL approved; CSA approved; Ontario Hydro Approved.
   b. ON--Push in; all power on; timing commences.
   c. OFF--Push up; all a.c. power off; no sampling; optional battery continues to run timer.

10. Fast Check on Operation of the Digital Timer/Programmer: The operation can be demonstrated or checked by setting all functions and then setting the clock in the FAST mode. The timer should start and stop on the programmed times. Note, however, that because of the digital logic in the timer, SAMPLING PERIOD can only be set to 24 hours for this fast check. Other sampling times cannot be used, even though in real time they will function properly.

ADDITIONAL ITEMS ONLY on Model 245 Automatic Sampler

11. MAXIMUM SAMPLES TAKEN Switch: Set to possible 20 samples. Determines how many filter positions the carousel should revolve until stopped or reset.

12. FILTER OVERLOAD Switch: If pressure across filter becomes too great to maintain ideal sampling conditions, carousel will advance to next set of filters for remainder of exposure when this switch is at AUTOMATIC FILTER ADVANCE. If switch is OFF then filters will not advance.

2.0 Operation of Sierra-Andersen Models 244 and 245 Dichotomous Samplers

2.1 General Operating Procedure

The following operating procedure is for both the Model 244 and 245 Sierra-Andersen dichotomous samplers.

1. Inspect the sampling module to ensure that it is clean and free of particulate deposition on its inner surfaces. Clean the bug screen if necessary. See Section 2.2.2 for cleaning details.

2. Bolt down the sampling module (optional). If desired, the sampling module can be bolted down to the roof of the monitoring station or other mounting surface.

3. a. For Model 244: Unscrew the knurled filter holder nuts by hand. Install the filter cassettes containing the preweighed 37-mm diameter Teflon filters in the sampling module (white ring-fine filter, yellow ring-coarse filter). Put both filter cassettes on the filter screens. The lower half of the cassette goes over the filter screen. The lower half is also the side having the shortest distance (approximately 1/16 in.) to the filter surface. Screw on both knurled filter holder nuts tightly by hand. The coarse-particle filter holder is the one with the 1/4 in. O.D. tubing and the fine-particle filter holder is the one with the 3/8 in. O.D. tubing. As shown in Figure 2.1, the filters can also be distinguished by the fact that the coarse-particle filter is on the

center line of the virtual impactor head and aerosol inlet, and the fine-particle filter is offset.

b. For Model 245: Open the carousel housing by undoing the 2 front knobs. The trap door on top of the housing is opened by undoing the thumb screw. After opening the trap door pull the brass hub off the carousel. The filter plungers should be in the down position enabling the carousel to slide forward out of the front of the housing. Load the filter cassettes into the carousel holes starting with position 1. The shallow side of the cassette faces down and the deep side faces up. Coarse particulate filters (yellow ring) are placed in the inside circle and fine particulate filters (white rings) are placed in the outside circle. Passive filters placed immediately behind the final active filter pairs will be exposed to the atmosphere if the sampler cycles ahead following the last active sample. Therefore, the pair of filters used to determine the passive loading should be placed in the final position in the carousel. Filter pairs are matched as if they were the spokes of the carousel wheel. Slide the tray back into position and replace the hub of the carousel (The carousel slides on two aluminum rails until into position.). The tray can be rotated to the home position by pressing the "HOME" toggle switch mounted in the upper left corner of the housing. All petri dishes must be retained for filter retrieval. Close and tighten the trap door and housing door to prevent weathering of samples.

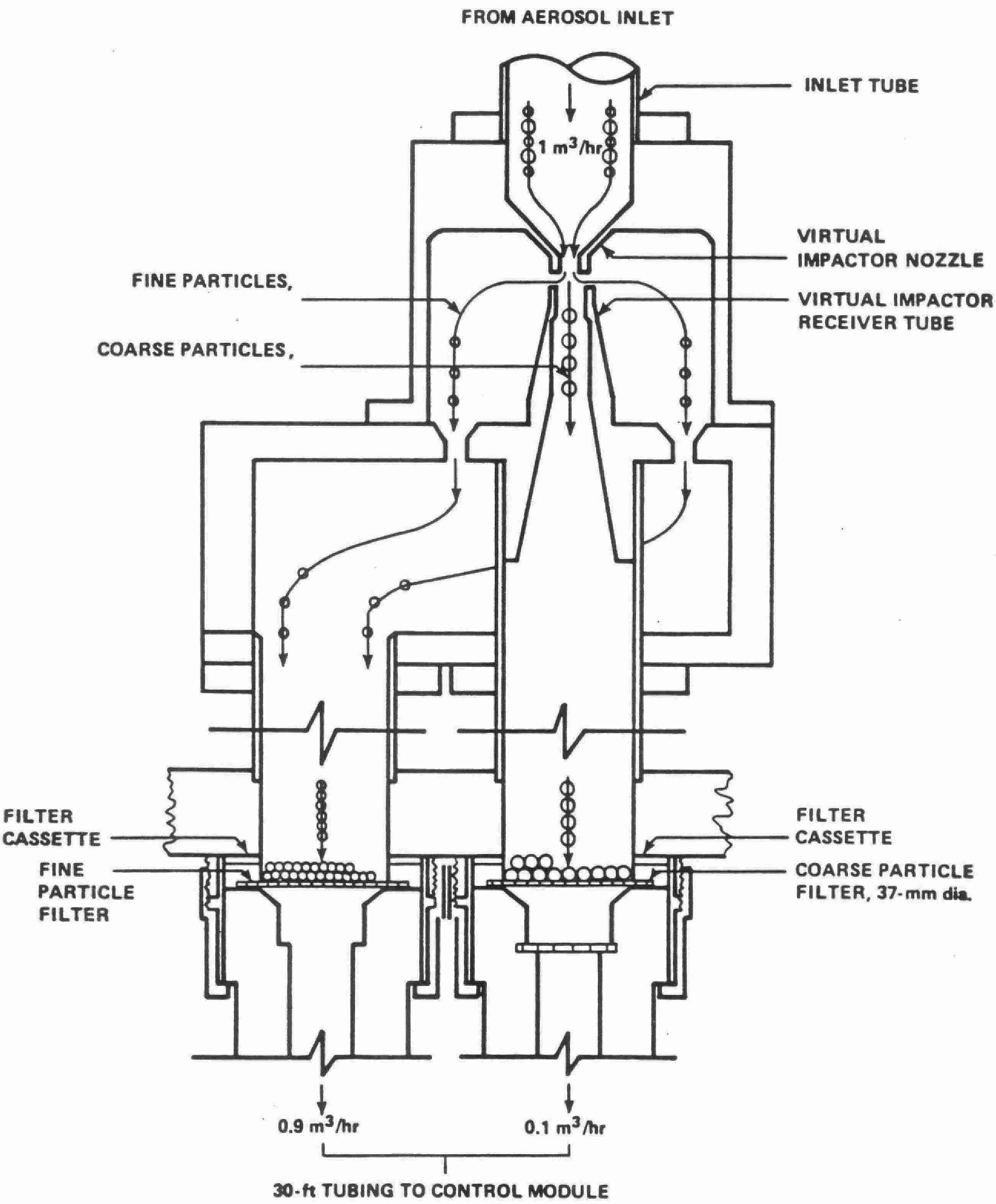


Figure 2.1. The Virtual Impactor: Principle of Operation

4. Connect the two vacuum lines. The 1/4 in. O.D. and 3/8 in. O.D. lines should be interconnected between the sampling module and the control module. First, hand-tighten the nuts on the tube connectors as much as possible and then wrench-tighten 1 1/4 revolutions. (Note: This may have been done already during sampler installation.)

5. Site the control module either next to the sampling module or remotely, as in a monitoring station. The control module may also be bolted down to its mounting surface if desired. The four bolt holes are 0.281 in diameter and are in a rectangular pattern with dimensions of 19 1/16 in. x 7 1/4 in. between centers.

6. Open the front cover of the enclosure of the control module. The latch is opened by turning the knob counter-clockwise and released by turning the indicator one-quarter turn counter-clockwise. It is locked by reversing this process.

7. Turn the SAMPLER Switch on the Model 302 digital timer/programmer to OFF.

8. Plug the male cord into line voltage-4: 115/60 Hz, 5 A maximum.

9. Turn the SAMPLER switch on the Model 302 digital timer/programmer to ON.

10. Depress the POWER switch on the Model 302 digital timer/programmer to turn on the vacuum pump.

11. The sampler is now ready to sample. In accordance with the procedure in Section. 2.1.1 (Model 244) and/or 2.1.2 (Model 245), set the master timer for the next operational sampling period.

12. Close the front cover of the control module.

13. After sampling, adjust the timer to turn the sampler back on. Record the final rotameter readings. Reverse the filter installation procedure to remove the filters. Put the filter cassettes in their original marked plastic petri dishes.

14. Record the sampling time from the elapsed time indicator.

15. Note and record if power failure has occurred.

2.1.1 Operating Procedure for Model 244 Digital Timer/Programmer

1. Open the cover of the sampler enclosure.

2. Turn the SAMPLER switch OFF.

3. Plug the male cord into line voltage.

4. Push the POWER switch ON (push in). The pump will turn on. Set the flow controller, etc., of sampler. (See Chapter on Calibration.)

5. Set SAMPLE START TIME of Day: (NOTE: Digits will flash until set.)

NOTE: SAMPLE START TIME must be at least 10 min. after TIME OF DAY. The DISPLAY Selector Switch must not be in the SAMPLE START TIME position 10 min. prior to sampling.

a. DISPLAY Switch: Set to SAMPLE START TIME.
b. FAST/SLOW Switch: Hold up or down as appropriate to set sample start time (24-hr format).

6. Set Standard Time of Day (NOTE: Digits will flash until set):

a. DISPLAY Switch: Set to TIME OF DAY.
b. FAST/SLOW Switch: Hold up or down to set present time of day (24-hr format).

7. Delay Start (Sample after X Days, 0-8 Days): Set SAMPLE AFTER switch to number of days to be skipped before first sampling period. Position "1" will initiate first sampling period the first time the TIME OF DAY = SAMPLE START TIME. Thus, for example, if the present time of day is 10:00 and the start time is 8:00, the first sample will start in 22 hours. Position "1" will delay the start 1 day (24 hours) after TIME OF DAY = SAMPLE START TIME. Position "2" will delay start 2 days (48 hours), etc.

8. Skip Timer (Sample Every Y Days, 1-9 Days):
Set the SAMPLE EVERY switch to initiate 1 sample each Y days. Position "1" samples every day. Position "2" samples every 2 days. Position "6" samples every 6 days, etc.

9. Sampling Period (Sample for Z Hours, 1-24 Hours):
Set the SAMPLE FOR switch for the number of hours the sampler is to remain on during each sampling period.

NOTE: The switches referred to in Steps 9, 10, and 11 are positive detent switches that provide exact timing. If the switch is not in the detent, it is not usable.

IMPORTANT: Steps 5, 6, 7, 8, and 9 can be done in any sequence but Steps 10 and 11 must be done last.

10. Set Timer:
Push SET switch down to TIMER position for approximate 2 seconds.

11. Timed Sampling:
Place SAMPLER switch in TIMER position. This initiates all timing functions.

12. Close door.

2.1.2 Operating Procedure for Model 245 Digital Timer/Programmer

1. Make sure carousel is in the first ("HOME") position.

2. Turn all switches down the right side of the control panel to the "OFF" position (i.e. "Line Power", "Battery Power", "Filter Overload", and "Sampler" switches should all be down).

3. Plug unit into line voltage.

4. Turn "Line Power" and "Battery Power" switches on (i.e. "up" position).

5. Clock will be flashing at a rate of 1 Hz (This tells the operator that the system was recently without power.). Set the clock to present time. Do this by moving "Clock Reads" switch up to "Present Time" position and moving "Set Clock" switch (fast or slow) until the digital clock reads the current time.

6. Set "Clock Reads" switch to "Sample Start Time" and programmed sampling time should light up. The "Clock Reads" switch must be returned to the "Present Time" position after the sampling times have been set.

7. If the sample start time is within the next 24 hours then set "Sample Starts On Day" switch to "1". If the sampling is to commence in greater than 24 hours but less than 48 hours then set switch to "2". Sampling can be set to start in up to 9 days. The zero is invalid, do not use.

8. Set "Sample Every" to "Day" and rotary switch to "03" if sampling on every third day. Set to "06" for every sixth day.

9. Set "Sample Duration In Hours" to "24" for 24 hour sampling.

10. Set "Maximum Samples Taken" to "20" if all filter positions are filled (i.e. 40 filters). Set to "03" if

only 3 samples (i.e. 6 filters) are in position (i.e. the first 3 positions).

11. Momentarily press the "Start-Restart" switch to initialize the new programming sequence. <u>This must be done after all other switches are set</u>.

12. Move "Sampler" switch to "Timer".

13. Close door.

NOTES: 1. Flashing time display indicates A.C. and battery power failure.

2. The Digital Elapsed Time Indicator (9999.99 hours maximum, nonresettable) records the total elapsed time the sampler has been on (both TIMED and ON positions of SAMPLER switch). A.C. power failure stops elapsed time indicator until power returns.

3. The power switch incorporates a circuit breaker. When the circuit is broken, the power ON button pops up. If more than 15 A are drawn, the circuit breaker will trip even if the button is held on (in). Reset is accomplished by pushing ON button in.

4. For manual operation, the timer can be bypassed by placing the SAMPLER switch in the ON position to independently turn the sampler on during noncycle periods. The OFF position

turns both timed and manual sampler power off.

2.2 Maintenance Procedures

2.2.1 Sampling Module--The sampling module is shown disassembled in Figure 2.2. All parts are sealed with "O" rings. Internal particulate deposits accumulate primarily on the outer and inner surfaces of the tip of the receiver tube in the virtual impactor head. The receiver tube should be inspected periodically for such particulate deposits and cleaned as required. A receiver tube cleaning schedule of every 3 to 4 months is desirable. The remaining inner surfaces should be cleaned every 6 to 12 months. Cleaning should be done with alcohol or water using a camel's hair brush. Disassembly and internal cleaning should normally not be attempted in the field.

The diametral "O" rings in the aerosol inlet and the flow splitting chamber should be conditioned periodically with vacuum grease.

2.2.2 Sampling Inlet Cleaning--The bug screen in the aerosol inlet should be cleaned periodically during the summer months. The inlet should be dismantled (unscrew top and bottom half) and cleaned (Figure 2.3). Large particles (>10 mm) deposit in the inlet and may build up after many months. The overflow bottle should also be checked and cleaned after every rainfall. Finally, the inlet should be checked for snow and ice buildup during winter months. On rare occasions snow may completely block off the air passage.

If this problem is recurring, an extended metal "brim" can be fitted to prevent snow from entering the inlet. These are specialty items available from A.R.B.

Once the inlet has been cleaned of dust and moisture, it should be re-fitted so that all seals are properly airtight. In particular, the overflow bottle must be flush with the lid, and the top and bottom halves of the inlet must be securely threaded. Re-connect the inlet to the inlet tube without tearing the rubber O-ring inside.

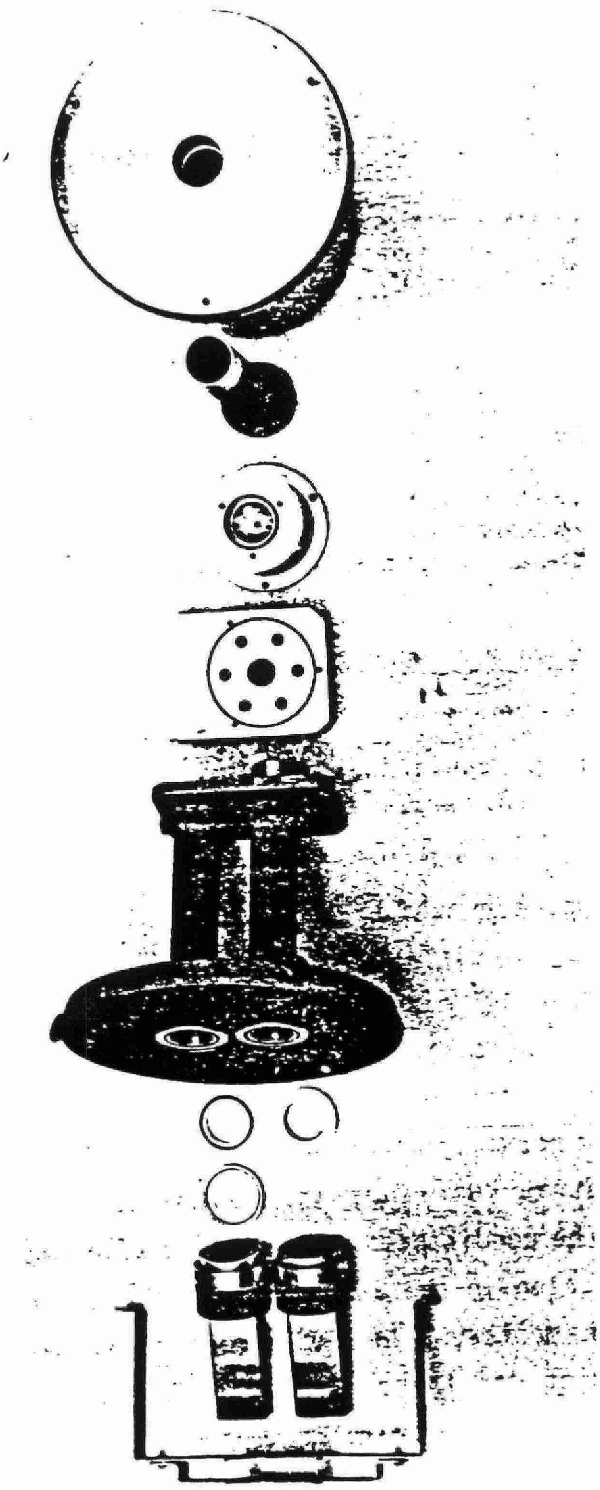


Figure 2.2. Disassembled Sampling Module of the Model 244

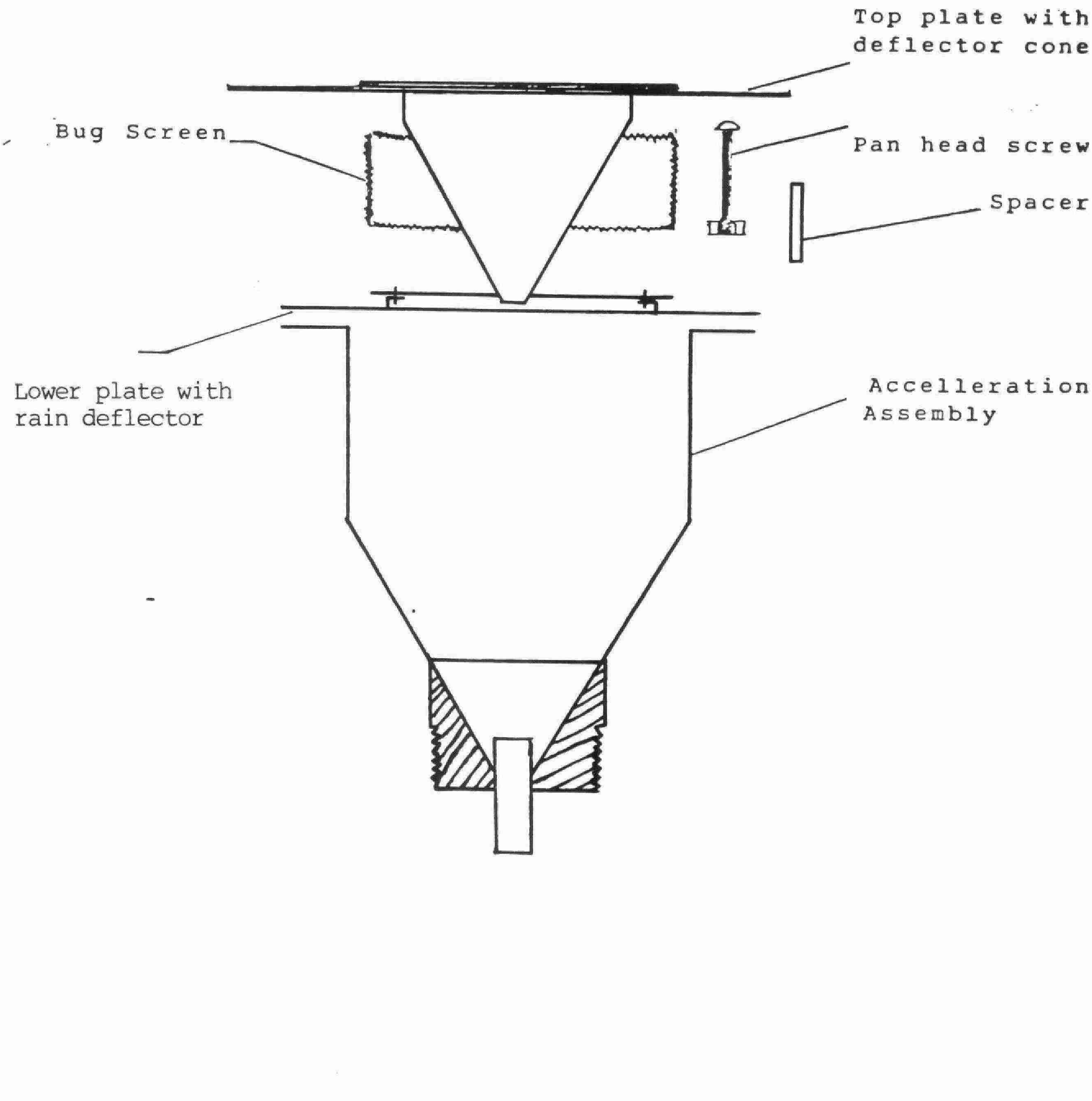


Figure 2.3. Sampling Inlet for Dichotomous Sampler Models 244 and 245.

2.2.3 Sample Module--This assembly initially should be inspected for any damaged or missing components.

NOTE: The virtual impactor assembly is extremely difficult to dismantle after a few months in the field (i.e. the heads of the Phillips screws are the weakest points). If the virtual impactor must be dismantled, use penetrating oil and the correct tools. Extreme care must also be used on reassembly. **The size fractionating characteristics of the sampler are highly dependent upon the set distances between the inner nozzles.** If the virtual impactor assembly is not replaced correctly, these distances may be out by less than a millimeter and the sizing of particles will be affected.

Use general purpose household cleaner, clean all interior surfaces, paying special attention to the various small nozzles and openings in the various components. Rinse with distilled water and dry thoroughly.

2.2.4 Maintaining Model 245 Sampling Module--The Model 245 sampling module is quite different from the Model 244. Although the inlet-virtual impactor sampling lines of the two models are identical, the filter holding apparatus mechanism on the Model 244 is designed for manual operation, whereas the Model 245 is designed for automatic operation. The Model 245's carousel filter holder system allows 20 samples (40 filters) to be programmed for sequential sampling. The filters are loaded into the sampling position automatically and unloaded if the sample integrity is compromised due to excessive filter resistance.

The carousel can be divided into 4 main sections:

1. The inlet-virtual impactor sampling line;

2. The revolving carousel filter holder;

3. The plunger mechanism;

4. The protective casing and legs.

The inlet-virtual impactor sampling line should be inspected and, if necessary, cleaned following every 20 filter-set sampling period.

The revolving carousel shifts filters into and out of the sampling position. The motor drive of the carousel is quite sturdy and rarely breaks down under strain (e.g. jamming and freezing). Instead other weaker parts tend to break.

However, it is imperative to make sure the carousel is positioned perfectly above the plunger mechanism. If the plungers do not fit perfectly through the filter holder holes, the carousel will jam. The positioning of the carousel when it stops revolving is controlled by a microswitch mounted in the deep left-hand corner of the carousel. The switch is activated by slots on the carousel disk edge. If the carousel does not position properly, or will not stop revolving, then this switch needs to be re-positioned or replaced.

The plunger mechanism is activated once the carousel stops. Two plungers (one fine and one coarse) spring up through the carousel holes and lift the filters into the sampling stream. Flat-faced rubber rings seal the filter into place. These rings must have a level edge. If the plunger freezes or jams, a plastic cam usually breaks to alleviate the stress. If this needs replacing, the housing must be unscrewed and raised to allow room to get at the components. After replacing, the carousel-microswitch-plunger mechanism should be realigned. Regular leak checks should be done to maintain a good sample O-ring seal. The alignment of the plunger-carousel should also be checked regularly.

The carousel housing should be kept weatherproof. Passive dust loading and rain leakage will ruin samples.

Finally, sampler connector tubing should be examined periodically and replaced as necessary.

2.2.5 Control Module Cleaning--To clean the control module:

1. Ensure that power is disconnected from the unit. If compressed air is available, open the unit and blow out loose dust and dirt.

2. Wipe down all surfaces with the general purpose cleaner and towels. Make note of any obvious problems in the unit and take action to correct them before completion of cleaning.

3. Check rotameters for cleanliness. If they are dirty and/or contain water, they must be removed and cleaned. (If water is found, the interior of the vacuum pump may be damaged. It will have to be opened for inspection and possible repair.) Rotameters are cleaned by the following steps:

   i) Remove the tubing from the total rotameter output port, and any other connected tubing that may prove too inflexible to allow removal of the rotameters.

   ii) Remove the four screws securing the rotameter assembly to the front panel.

   iii) Slip the assembly back from the front panel enough to gain access to the allen screws on the top of

each of the rotameters. Remove the protective covers from each rotameter.

iv) While holding the glass rotameter with one hand, loosen the large allen screws just enough to allow removal of the unit. Repeat for each unit.

v) Clean the two rotameters with a light cleaner, followed by a thorough rinsing with distilled water. (To properly clean the unit, the float and its retainers should be removed. The retainers are easily removed with the aid of a wire hook fashioned from a paper clip.)

vi) Allow the tubes to dry thoroughly then reassemble.

4. Vacuum pump filters: Remove and clean all filter jars (check each for possible breaks and replace if necessary). Clean or replace all dirty filter elements.

5. Cooling fan: Clean the fan's blades and housing. Check the housing for any dirt buildup that could cause the fan to lock up.

6. Vacuum pump: Clean exterior surfaces of the unit, ensuring that all cooling vents are open. Check all mounting brackets to ensure that they are tight and in good repair.

7. When all cleaning operations and necessary repairs have been completed, close the module and reconnect the sample module to allow performance of leak and calibration checks.

2.2.6 Shelters--have been provided to protect the sampler from inclement weather. The shelters were designed and approved by MOE personnel for use with the Model 245 sampler. The control panel and carousel of the dichotomous sampler sit in the shelter while the inlet protrudes from the top. The doors open to both sides to prevent winds from upsetting filters while they are exchanged. A heating device can be placed in the shelter during the winter months to prevent freezing of the sampler. The heat of the pump may raise the temperature to 40°C in summer months if the sampler is not well ventilated. The shelters appear to have reduced the frequency of sampler breakdowns.

2.3 Common Breakdown Items

Certain items cause 95% of all breakdowns. A list of these items follows.

2.3.1 Synchronous motor (plunger assembly) Part #245-41

A synchronous motor is used to raise and lower the filter plungers against a set of springs. The motor is the weakest part of the assembly and is the first to fail when the carousel system freezes or jams. Originally a plastic cam was the weakest link, however these were replaced with brass cams and the synchronous motor is now the weakest item. This item is responsible for approximately 75% of all the breakdowns. Usually the plunger assembly must be removed from the carousel and the motor replaced. The incidence of this breakdown has been reduced by the use of shelters.

2.3.2 Inlet Welds

Inlet tubes welded to the carousel body may snap if handled roughly. Anodized aluminum does not make a strong weld and if the carousel is

carried by the inlet the seal will snap. Specialized welding shops can repair this, however all gaskets should first be removed and the surfaces cleaned.

2.3.3 Pressure switches Part #240-109

The pressure switch will advance the filter tray when particulate build-up impedes the proper air flow through the system. These items are easily tested by placing the palm of the hand over the inlet (with filters in place) and allowing the pressure to build in the sampling train. At approximately 20 psi the pump should disengage and the filters will advance. If the pressure switch is broken, the sampler will continue to pump.

2.3.4 Timers

Timers may fail due to corrosion of wiring and electronic components. Individual switches may not be making contact and may need cleaning or replacement.

2.3.5 Plunger Gaskets Part #245-30 or 245-31

Ribbed rubber gaskets are used to seal the filter cassette during sampling. If the gaskets are displaced or deformed, the seal will leak. The gaskets may be replaced or reset. Gaskets are available from Levitt Safety Ltd.

2.3.6 Inlet Plugging

The 10 um inlet head has become packed with snow on at least one occasion. A driving snowstorm in Sudbury packed the inlet closed and plugged the sampling train. Usually the inlet would allow excess water to run off into a catch jar, however the snow froze into position due

to cold weather conditions. Although this has not occurred since, an extended inlet plate has been manufactured to impede large snowflakes from entering the inlet. This was designed by Sierra-Andersen and is currently being used in Sudbury.

2.3.7 Vacuum Pump Part #240-38

The diaphragm of the Model 727CA418 Diaphragm Vacuum Pump is replaced if sudden reductions in sampler vacuum occur and a leak check indicates there are no leaks in the system.

To replace the diaphragm, unplug the line voltage and remove the front panel. Remove the four diaphragm plate holddown screws and change the diaphragm. To reassemble, reverse the procedure making sure that the screw clearance cavity in the plate is lined up under the intake valve screw heads and that all head screws are tightened evenly.

Maintenance of the samplers should be performed by the site operators on a regular basis. Data are rarely available for assessment until 2-3 months after sampling, therefore, a malfunctioning sampler will go undetected for some time if the technician does not maintain it. The program leader must be notified verbally, followed by writing, as soon as a malfunction is detected. See Q.A. Plan for specific instructions.

PARTS LIST FOR
FIGURE 2.4 MODEL 245 VIRTUAL IMPACTOR SAMPLING MODULE ASSEMBLY

Part No.	Description
240-139	O-RING
240-84	FLOOR SEPARATOR CHAMBER
240-137	O-RING
245-10	CAROUSEL SPINDLE CAP, TOP
245-3	TOP PLATE WELDMENT
245-18	CAROUSEL FILTER RETAINER
245-7	CAROUSEL SUPPORT BRACKET
245-8	BRACKET, CAROUSEL MOTOR
245-8A	CAM SWITCH BRACKET
245-9	CAROUSEL SPINDLE, BOTTOM
245-20	PLUNGER GUIDE BRACKET
245-24	CAROUSEL CENTER SUPPORT
245-43	MICRO SWITCH
245-55	HOME SWITCH
245-40	CAROUSEL MOTOR 110V/60 Hz
245-30	UPPER SEAL(BIGGER)
245-31	LOWER SEAL (SMALLER)
245-21 ASSY.	PLUNGER ASSY. COM. LESS 245-23
245-22	PLUNGER SPRING
245-23	CAM PRESSURE PLATE
245-29	BRASS ROD FOR CAM EXTENSION
245-15	CAM MOTOR MOUNTING ANGLE
245-16	CAM/COUPLING
245-17	CAM/BUSHING
245-25	SPACKER 1.25" LONG
245-41	CAM MOTOR UP-DOWN 110V/60 Hz
245-14	SUPPORT ANGLE, CAM SHAFT, SWITCH
245-4	MAIN SUPPORT BRACKET
245-4A	CAM ASSY. BRACKET MAIN SUPPORT
245-4B	MOTOR SUPPORT BRACKET
245-5	ENCLOSURE BOTTOM PLATE
245-6	245-4, SUPPORT BRACKET
245-12	SUPPORT LEG
245-28	LEG STIFFENER

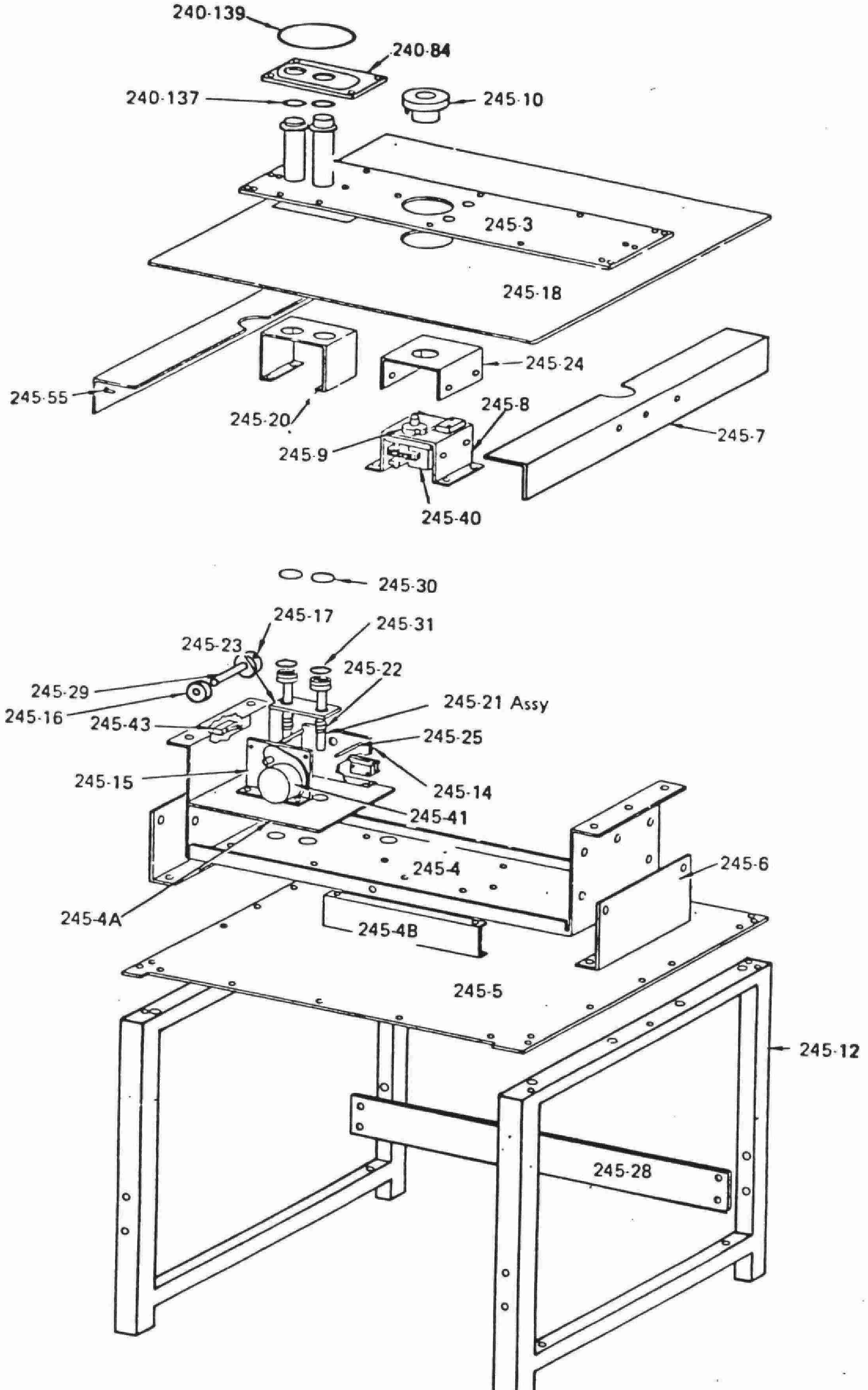


Figure 2.4. Model 245 Virtual Impactor Sampling Module Assembly.

PARTS LIST FOR
FIGURE 2.5 MODEL 245 VIRTUAL IMPACTOR ASSEMBLY

Part No.	Description
245-11	CAROUSEL SPINDLE ACCESS. DOOR W/GASKET
245-2	ENCLOSURE
245-19	GASKET 245-3 ENCLOSURE
245-13	MAIN ENCLOSURE DOOR
245-33	LOCK WITH 2 KEYS
245-34	LATCH ON 245-13
245-32	CAROUSEL INDEX/LABEL STICKER
245-1	CAROUSEL WITH STICKER
245-26	CONNECTOR COVER
245-27	HARNESS/UMBILICAL 7.5m LONG

The following not shown in Figures.

245-35	HEYCO #2873 BUSHING
245-36	HEYCO #3216 LIQUID TIGHT BUSHING
245-37	SMALL WIRE TIES
245-38	CABLE CLAMPS
245-39	4-40 CUP NOSE SET SCREWS
	FILTER ELEMENT FOR PART 240-102 ONLY
	FILTER ELEMENT FOR PART 240-103 ONLY
	FILTER ELEMENT FOR PART 240-131 ONLY
	JAR FOR PART 240-102 ONLY
	JAR FOR PART 240-103 ONLY
	JAR FOR PART 240-131 ONLY
	DIAPHRAGM FOR PART NO. 240-38
	MOTOR FOR 7 DAY RECORDER SPECIFY V & F OR VDC

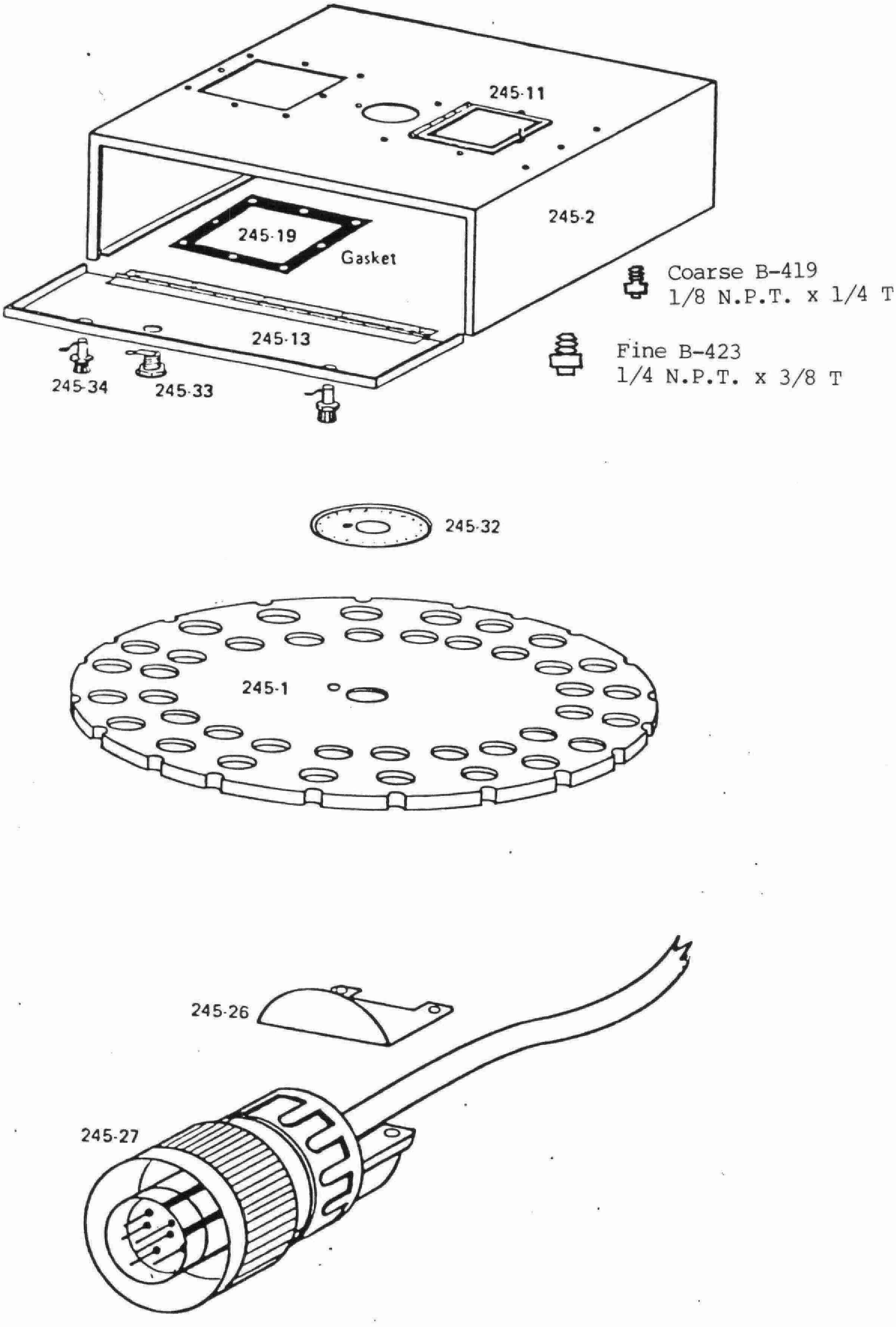


Figure 2.5. Model 245 Sampling Module (continued).

PARTS LIST FOR FIGURE 2.6 MODEL 245 ENCLOSURE

Part No.	Description
240-22	HANDLE
245-44	ENCLOSURE
240-102	FINE INLET JAR COMPLETE
240-103	COARSE INLET JAR COMPLETE
240-59	LATCH
240-58	LOCK WITH 2 KEYS
245-45	2 WEEK EVENT RECORDER
245-46	THUMB SCREW KNOBS
245-50	ELAPSED TIME INDICATOR SPECIFY V & F
245-51	245 CIRCUIT BOARD WITHOUT FRONT PANEL & POWER SWITCH
245-52	CIRCUIT BOARD FRONT PANEL WITH POWER SWITCH
240-54	ENCLOSURE FRONT PANEL, BARE
240-109	PRESSURE SWITCH
240-110	FITTING
240-111	FITTING
240-116	VACUUM GAGES
240-112	FITTING
240-113 TO 115	FITTING
240-118, -119	FITTING
245-47	COARSE FLOW ROTAMETER
245-48	FINE FLOW ROTAMETER
245-49	ROTAMETER BRACKET
240-124	FITTING
240-128	FITTING
240-43	FITTING
240-129	FITTING
240-130, -99	FITTING
240-140, 141, 142	FITTING
240-143	FLOW CONTROLLER
245-42	PULSATION DAMPER JAR COMPLETE
240-131	FILTER JAR COMPLETE
240-132, -133	FITTING

240-38	MOTOR
240-138	FAN WITH CORD
245-53	POWER CORD HARNESS
240-72	VIBRATION ISOLATOR

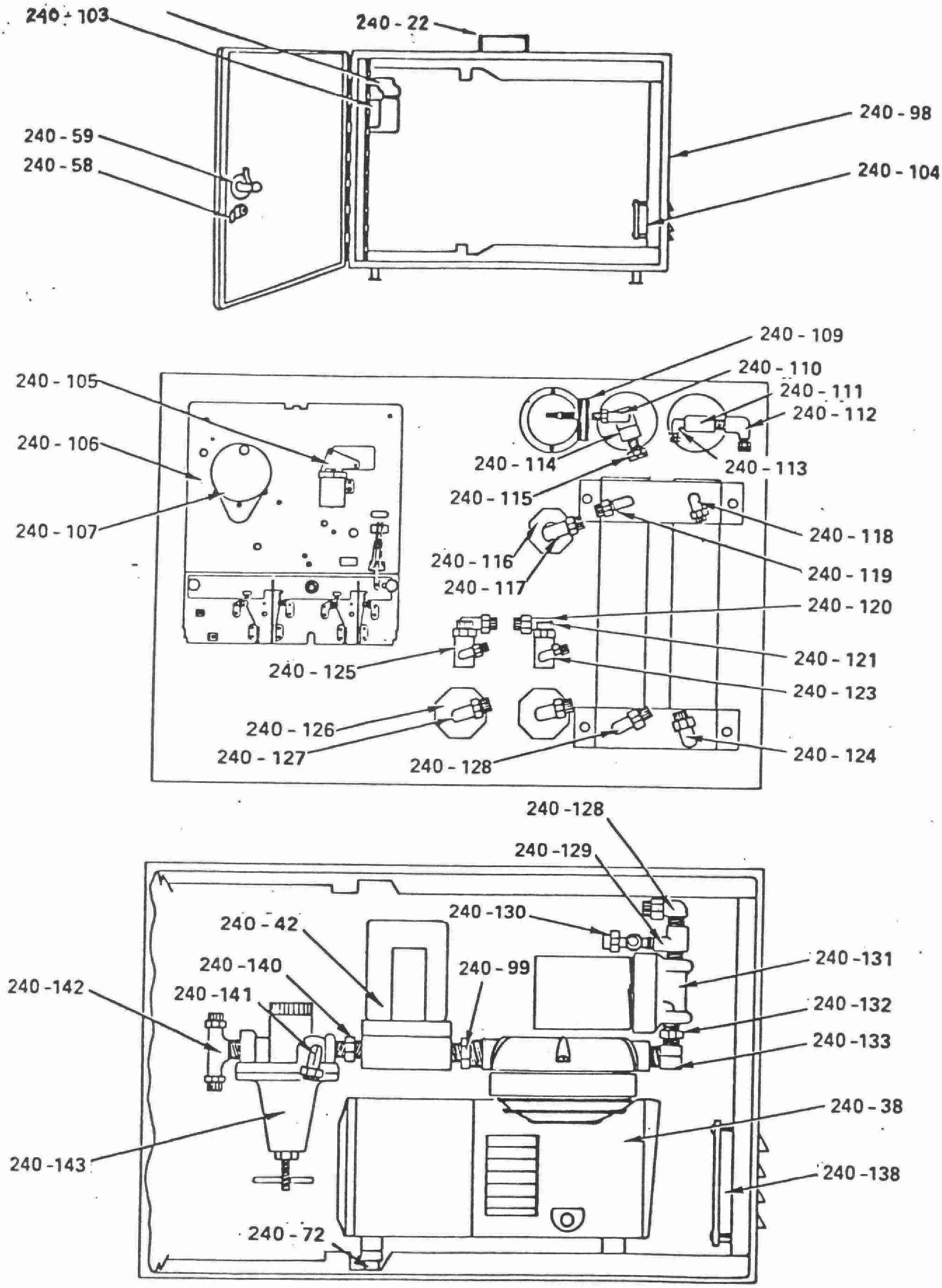


Figure 2.6. Control Module Assembly.

PARTS LIST FOR FIGURE 2.7 - DICHOTOMOUS INLET

Part No.	Description
246-P1	TOP PLATE WITH DEFLECTOR CONE
246-P2	6-32 X 1½ S.S. PAN HEAD SCREWS
246-P3	SPACER
246-P4	BUG SCREEN
246-P5	LOWER PLATE WITH RAIN DEFLECTOR
246-P6	ACCELLERATION ASSEMBLY
246-P7	COLLECTOR ASSEMBLY
246-P8	FITTING
246-P9	CAP
246-P10	RAIN JAR
246-P11	O-RING

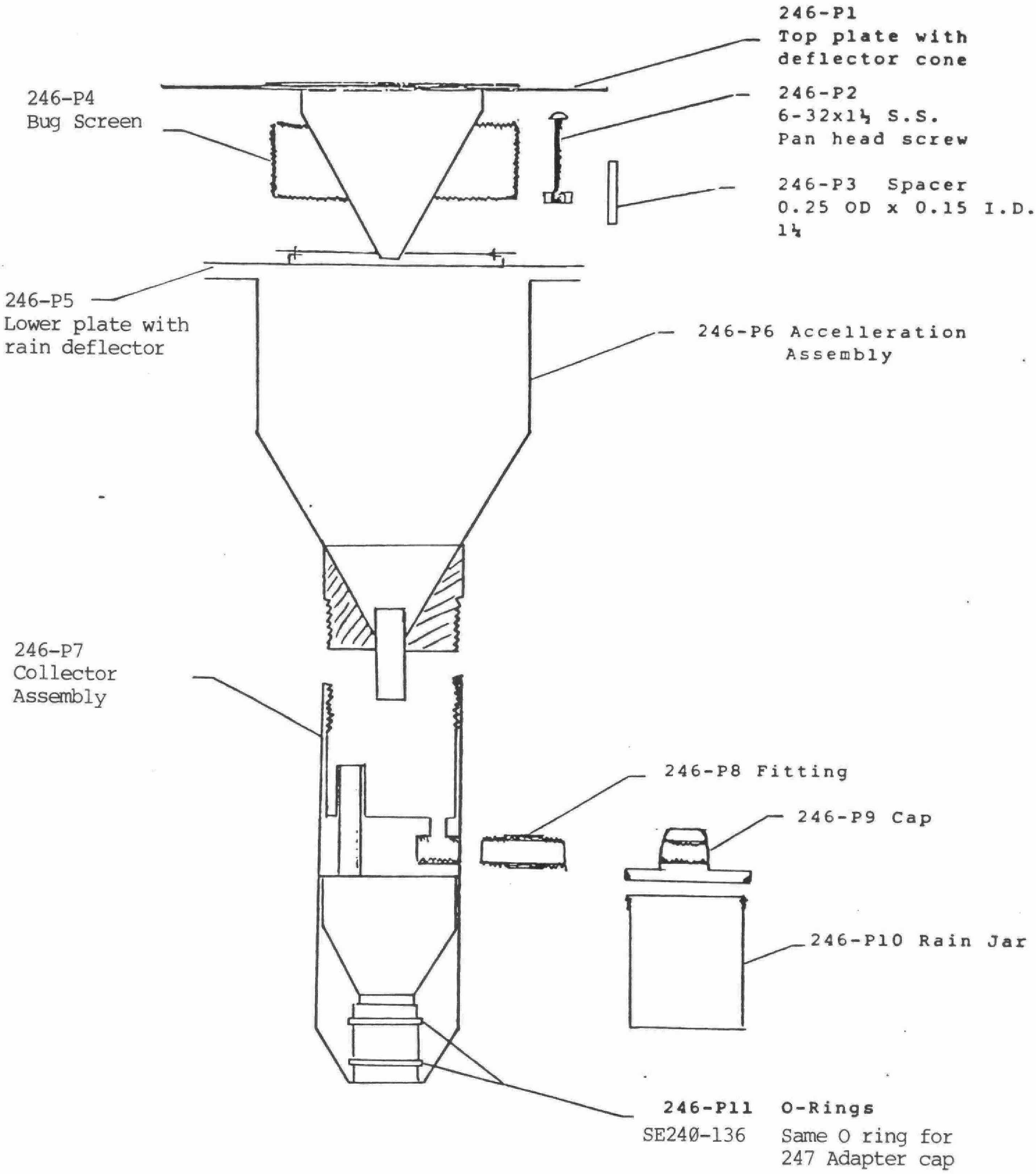
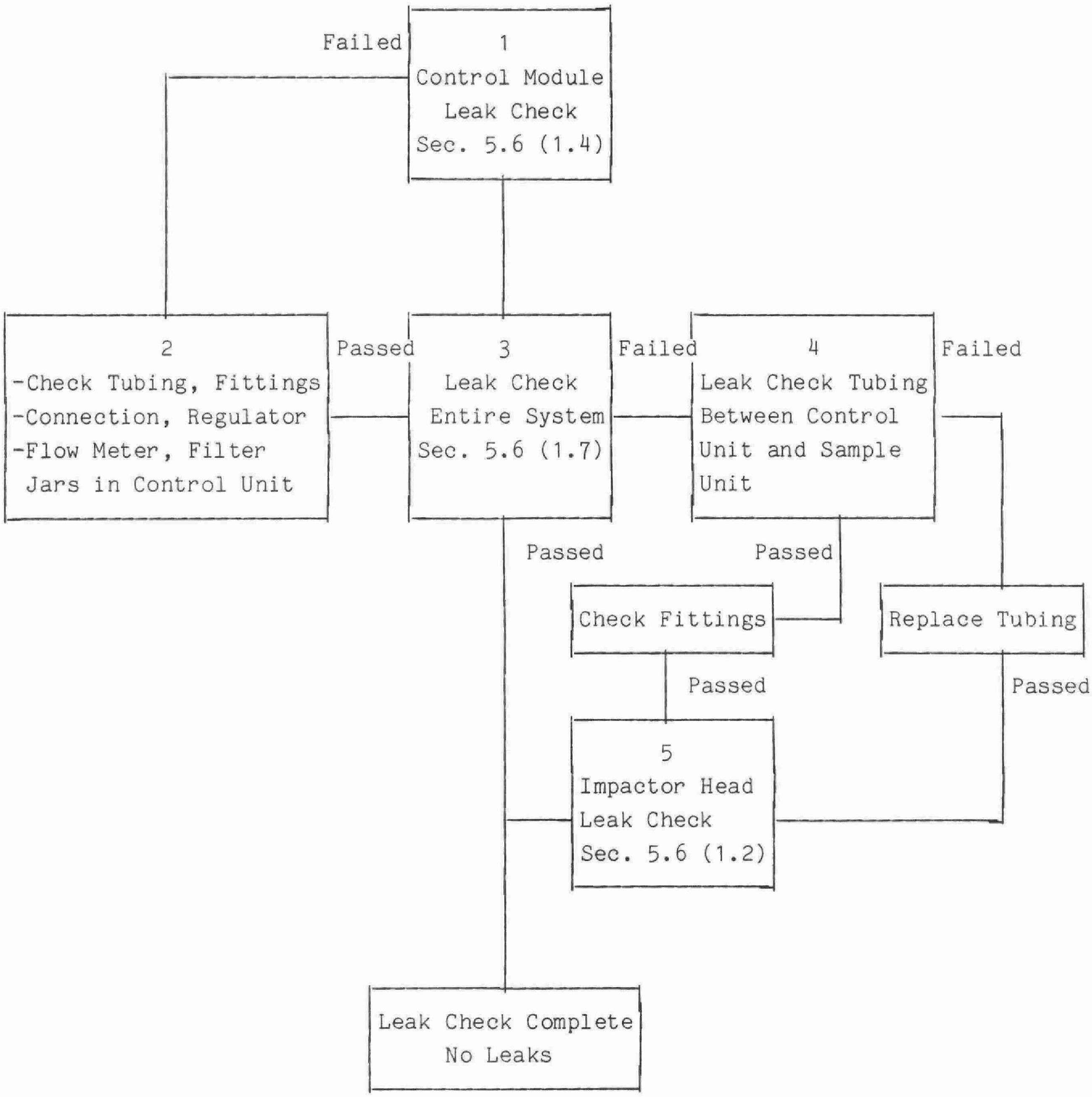


Figure 2.7. Dichotomous 10 um Sampler Inlet.

3.0 Calibration of the Dichotomous Sampler

This chapter describes the proper method of calibrating dichotomous samplers. Most instructions are taken from the Sierra Dichotomous Sampler Operating Instructions. A number of forms have been designed by the technical support staff of West-Central Region for network use. Forms are filled out by the field technician during the calibration check. Once completed, the forms should be checked by the technical supervisor and kept in the regional instrument files for at least 18 months. This should allow enough time for data analyses (e.g. modelling, year-end summary, etc.) to be completed.

FLOW CHART FOR CHECKING SYSTEM FOR LEAKS



3.1 Control Module Leak Check

3.1.1 Leak Checking

Leak checking should be conducted at the Control Module before calibration to assure that leaking does not affect calibration.

1. Plug both the fine-particle flow and coarse-particle flow bulkhead female pipe threads with either pipe plugs or with one's fingers.

2. Turn unit on manually and allow vacuum gauges to reach 20 to 25 in. Hg.

3. Turn off pump.

4. Pointers on the vacuum gauges should drop from 25 in. Hg to 5 in. Hg in approximately 10 to 12 seconds. If the rate of vacuum loss is greater than this, check for leaks using the following procedure:

3.1.2 If check fails then:

If pressure drop does not hold required time, unplug Control Module from electrical outlet and follow this procedure:

1. Remove instrument panel of Control Module.

2. Check all tubing fittings inside Control Module for tightness.

3. Check all filter jars for tightness.

4. Replace instrument panel.

5. Plug cord into electrical outlet.

6. Repeat above procedure.

If pressure drop holds, go to reassembly and leak-checking of entire system.

3.1.3 <u>Reassembly and leak-checking entire system</u>:

1. Install the tubing fittings and tubing as they were.

2. Remove Aerosol Inlet from inlet tube and install Model 247 Total Flow Audit Adapter over the inlet tube making sure the "O" ring is in engagement.

3. Turn pump on manually.

4. Plug tube fitting of Total Flow Audit Adapter with your finger.

5. Both vacuum gauges should reach 20-25 in. Hg vacuum.

6. Turn off pump and observe rate of vacuum drop.

7. Pointer should drop from 20 in. Hg to 5 in. Hg in approximately 10 to 20 seconds.

3.1.4 Leak Check Failure

If rate of vacuum loss is greater, check for leaks using the following procedure: Disconnect tubing from enclosure of Sampling Module and plug ends of tubing with one's fingers. If rate of vacuum loss is acceptable, the problem is in the impactor head and not in the tubing.

3.1.5 Impactor Head Leak Check

1. Make sure filter holders, seals and "O" rings are in place and not cut or marred.

2. Tighten all loose screws.

3.1.6 Tubing/Fitting Leak Check

1. Visually inspect tubing for cracks or holes.
2. Visually inspect tubing fitting ferrules for cracks.

Note: The correct way to tighten the polyflow fittings is to tighten 3/4 of a turn past finger tight.

TECHNICAL CHECK FORM 1

1. Both Bulkhead Plugged ______________

2. Pump Turned On ______________

3. Vacuum Gauge Total _________ in Hg (20-25 in Hg)

4. Vacuum Gauge Course ________ in Hg (20-25 in Hg)

5. Turn Pump Off _________

6. Elapse Time

Elapse Time	Vacuum in Hg	
0 Sec	___________	
5 Sec	___________	
10 Sec	___________	(Should drop to 5" Hg after 10-12 Sec)
15 Sec	___________	
20 Sec	___________	

Performance Failed ________ Passed ________

Comments:

____

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____

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Technician Signature: __________________________

Supervisor Signature: __________________________

TECHNICAL CHECK FORM 2

1. Place Rubber Stopper Over Inlet ______________
2. Shut Auto Advance ______________
3. Turn Pump On ______________
4. Vacuum Gauge Total __________ in Hg (20-25 in Hg)
5. Vacuum Gauge Course _________ in Hg (20-25 in Hg)
6. Turn Pump Off __________ (Pull Plug)
7. Elapse Time

Elapse Time	Vacuum in Hg	
0 Sec	____________	
5 Sec	____________	
10 Sec	____________	(Should drop to 5"
15 Sec	____________	Hg after 10-12
20 Sec	____________	Sec)

8. Removed rubber stopper and install inlet adaptor. Repeat steps 2 through 7.

9. Leak check all 20 spots on carousel.

1.	___	___	6.	___	___	11.	___	___	16.	___	___
2.	___	___	7.	___	___	12.	___	___	17.	___	___
3.	___	___	8.	___	___	13.	___	___	18.	___	___
4.	___	___	9.	___	___	14.	___	___	19.	___	___
5.	___	___	10.	___	___	15.	___	___	20.	___	___

Performance Failed _________ Passed _________

Comments:

____

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____

Technician Signature: ____________________________

Supervisor Signature: ____________________________

3.2 Flow Calibration

3.2.1 Calibration Flowmeters

The flow rates are calibrated with a precision mass flowmeter. If bubble meter, wet test meter, dry test meter, laminar flow element, precision orifice meter, or precision laboratory rotameter are used, it must be noted on field forms.

3.2.2 Calibrating the Total Flow Rate, Q_T

The total flow rate Q_T can be calibrated in two locations - at the inlet of the system and the exit of the system. Flow Calibration at the inlet is best because it checks the entire system.

3.2.3 Calibration at Inlet

1. Remove the Aerosol Inlet from the 1.25 in. O.D. inlet tube by pulling it off vertically. An "O" ring in the Aerosol Inlet affects the seal.

2. Place the Model 247 Total Flow Audit Adapter over the inlet tube and push down vertically. An "O" ring in the Model 247 effects the seal.

3. Using flexible tubing connect the hose bib on the Model 247 to the calibration flow meter.

4. Turn the pump on. Turn "FLOW ADJUST" knob above "TOTAL FLOW" on the instrument panel of the Control Module to set the precise 1 CMH (16.7 LPM) flow rate.

5. Record the reading on the "TOTAL FLOW" rotameter. This is an accurate "transition standard" for the calibrated flow rate.

3.2.4 Calibration at Exit

1. Remove the instrument panel of the Control Module.

2. Locate the total flow exhaust port (1/8" NPT) on top of the total flow rotameter.

3. Screw a tube fitting into this port and connect with tubing to the calibration flowmeter.

4. Turn pump on. Turn "FLOW ADJUST" knob above "TOTAL FLOW" on the instrument panel of the Control Module to set the precise 1 CMH (16.7 LPM) flow rate.

5. Record the reading on the "TOTAL FLOW" rotameter. This is an accurate "transition standard" for the calibrated flow rate.

   CAUTION: The pressure drop in the calibration flow meter should be minimal and should not exceed 0.05 in. Hg.

3.2.5 Calibrating the Coarse-Particle Flow Rate, Q_c

1. The coarse-particle flow should be calibrated at the Control Module using the 1/8" NPT bulkhead fitting on the side of the enclosure.

2. Disconnect 1/4 in. O.D. coarse-particle flow tubing and fitting.

3. Connect calibration flowmeter to the 1/8" NPT female bulkhead pipe fitting.

4. Turn pump on. Turn "FLOW ADJUST" knob above the "COARSE-PARTICLE FLOW" rotameter on the instrument panel to the calibrated flow rate of 0.1 CMH (1.67 LPM).

5. Record the reading of the "COARSE-PARTICLE FLOW" rotameter. This is a "transfer standard" for the calibrated coarse- particle flow.

3.2.6 Calibrating the Fine-Particle Flow Rate, Q_f

1. Disconnect 3/8 in. O.D. fine-particle tubing and fitting.

2. Connect calibration flowmeter to the 1/4" NPT female bulkhead pipe fitting.

3. Turn pump on. Turn "FLOW ADJUST" knob above "TOTAL FLOW" on the instrument panel to the calibration flow rate of 0.9 CMH (15.0 LPM).

4. Record the reading of the "TOTAL FLOW" rotameter on the instrument panel. This is a "transfer standard" for the calibrated fine-particle flow. Note that the reading recorded from the "TOTAL PARTICLE FLOW" rotameter flowmeter is <u>not</u> the fine-particle flow. The fine-particle flow is the difference between the total flow Q_T and the coarse-particle flow Q_C.

FLOW CALIBRATION

TOTAL FLOW INLET CHECK
(Mass Flow Meter)

1. Mass Flow Setting ________ (LPM (16.7)
2. Rotameter Setting ________
3. Vacuum Gauge Setting ______ (.5 to 2 in Hg)

COURSE - PARTICLE FLOW RATE
(Using Bubblemeter)

1. Bubblemeter Flow Rate _________ LPM (1.67)
2. Rotameter Setting ___________
3. Vacuum Gauge Setting _________ in Hg ("0")

FINE PARTICLE FLOW RATE
(Using Mass Flow Meter)

1. Mass Flow Meter Setting _________ LPM (15.0)
2. Rotameter Setting Total Flow _________

Performance Failed _________ Passed _________

Comments:

____
____
____
____
____
____

Technician's Signature: ________________________

Supervisor's Signature: ________________________

3.3 Automatic Pressure Switch

A pressure switch, shown in Fig. 3.1, terminates sampling when the fine-particle filter overloads. Switching occurs when the pressure drop (P_a-P_3) across the fine-particle filter increases beyond 38 ±2.5 cm Hg, which coincides with the limit to which a constant flow can be maintained. When switching occurs, the digital programmer automatically indexes a pair of clean filters into the sampling positions, and the remainder of the pre-selected sampling period is completed. The flow-event recorder gives the time of indexing.

Test this switch by placing hand or adaptor/valve over inlet tubing, or over control module bulkhead fitting. As pressure drops read vacuum gauge and record setting at which pump shuts off.

3.4 Setting Pressure Differential P_1-P_a

The flow controller maintains a constant pressure differential (P_1-P_a) shown in Figure 3.1. This pressure differential is set in the factory at its optimum value of 4 in. Hg. P_1-P_a can be anywhere in the range of 2 to 6 in. Hg without seriously degrading the performance of the constant flow controller. To check P_1-P_a, first unplug the line power cord from its receptacle, remove the front panel, locate the P_1 pressure port located in a tee above the air-line filter with plastic jar located on top of the vacuum pump (exhaust side), remove the 3/8" tube plug, and insert and tighten a 3/8" tube connected to a mercury manometer or pressure gage with the low pressure side open to atmosphere.

If P_1-P_a is out of the 2 to 6 in. Hg range, readjust by turning the black knob of the flow controller located on the inlet side of the vacuum pump. The flow controller looks like a pressure regulator. The locking screw must first be unloosened. Turning the knob clock-wise increases P_1-P_a. After adjusting, be sure to tighten the locking screw and reinsert and tighten the 3/8" tube plug in the P_1 pressure tap to avoid leaks.

3.5 Flow-event Recorder

The flow-event recorder is a 10cm (4 in.) diam. circular chart pressure transducer recorder (See Figure 3.2). The chart is marked in days and hours and makes one revolution every 2 weeks. The pressure range is 0 to 6 in. Hg. The pressure transducer measures the pressure drop P_1-P_a across the total flow selector valve, which is a measure of the total flow rate. P_1-P_a is maintained constant at nominally 4 ±1 in. Hg by the constant flow controller. The recorder will read 4 in. Hg whenever the sampling pump is on and will be zero when it is off. The recorder, therefore, provides a hard copy record of flow and events. The flow-event recorder will show a radial line to zero pressure when the pressure switch senses filter overload. It usually is not necessary to know the exact time of pressure switch activation because the extra filters required to fulfill a sampling period can be weighed together with the primary filter to obtain the average mass concentration over the pre-selected sampling period.

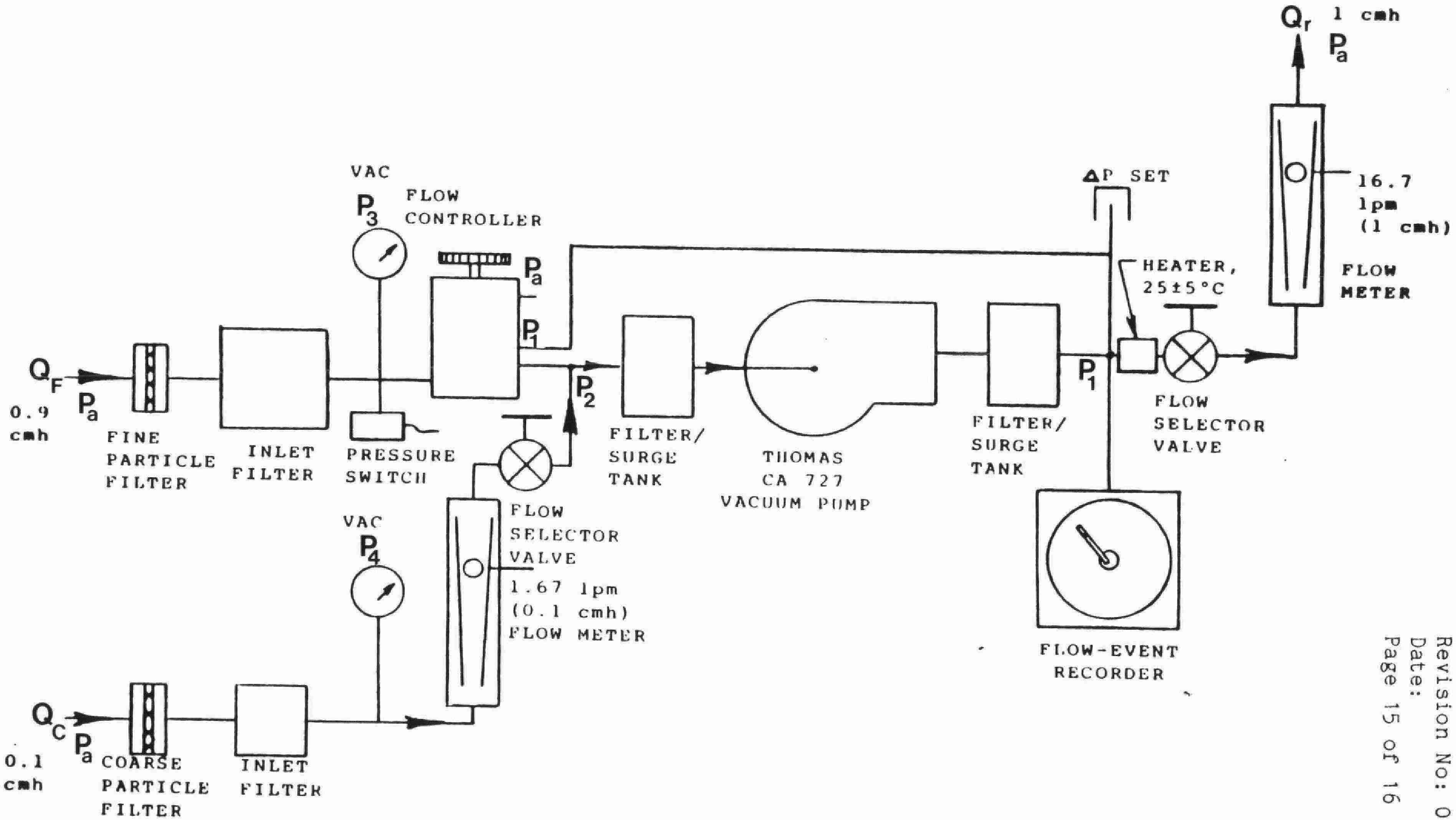

Figure 3.1. Schematic of Dichotomous Flow System.

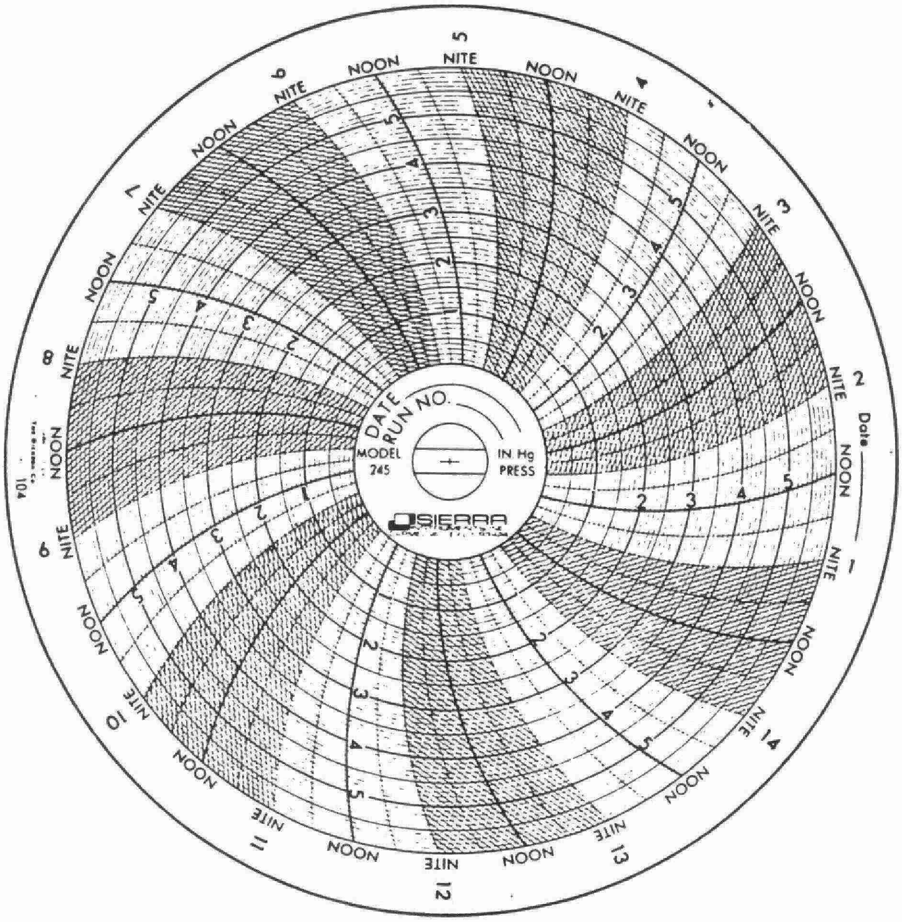

Figure 3.2. Circular Flow Recording Chart.

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